CRETACEOUS AND TERTIARY COCCOLITHS FROM ATLANTIC SEAMOUNTS

by MAURICE BLACK

ABSTRACT. Fragments of white chalky limestone dredged from Galicia Bank off the west coast of Spain contain coccoliths of two different ages. At a station on the northern slope, all the fragments have coccoliths of Middle Eocene age; the same species are also present on Muir Seamount, north-east of Bermuda, but are unknown in any rock exposed on land. In a sample from the underwater escarpment on the east side of Galicia Bank, only Cretaceous species can be recognized. Material dredged from the top of the bank has an intimate mixture of well-preserved Maestrichtian and Middle Eocene species in the same rock. This composite assemblage is believed to have been brought together by mud-feeding organisms which burrowed through a thin layer of Eocene sediment into an unconsolidated Cretaceous ooze below. Three new genera, *Colvillea*, *Ericsonia*, and *Favocentrum*, and eleven new species, are described.

THE purpose of this communication is to describe a few previously unnamed coccoliths which have been used in dating a collection of soft chalky limestones dredged from the Iberian Seamounts in 1958 by R.R.S. *Discovery II* (Black, Hill, Laughton, and Matthews 1964). A list of dredging stations with their latitudes and longitudes will be found on p. 315.

The rocks in question are firm but uncemented limestones, rather like ordinary chalk in appearance and texture, and no harder than much of the Yorkshire Chalk. Most specimens are white, sometimes with a grey infiltration of manganese dioxide or a yellow stain of ferric hydroxide. The sample from Station 4272 on Galicia Bank is strongly iron-stained, and the preservation of the coccoliths is poor. Samples from Station 4279 on Vigo Seamount are even more heavily impregnated with ferric hydroxide, and although coccoliths could be seen in polarized light, none could be identified specifically.

Cretaceous species were present at Stations 3804, 3809, and 4272. Counting of individual coccoliths showed that at Station 3804 about half belonged to various Upper Cretaceous species; at Station 3809 the proportion was one-fifth, and at Station 4272 all the identifiable coccoliths belonged to a single Maestrichtian species. In addition to *Zygrhablithus cretaceus* (Archangelsky), *Colvillea barnesae* (Black), and *Microrhabdulus decoratus* Deflandre, which are well-known Upper Cretaceous forms, there were several previously undescribed species which in East Anglia and Denmark are confined to the Maestrichtian stage. These are described below as species of *Favocentrum* and *Coccolithites*.

At Stations 3804 and 3809 the samples also contained substantial proportions of the Eocene species to be mentioned below, and smaller numbers of *Gephyrocapsa oceanica* Kamptner, *Coccolithus pelagicus* (Wallich), and *C. huxleyi* (Lohmann), which are common in the modern plankton off the Iberian coast. The presence of a few modern coccoliths is not surprising, since porous rocks lying exposed on the sea-floor very readily become contaminated in this way. The Tertiary coccoliths, on the other hand, are much too numerous to have been introduced by casual contamination, and suggest a thorough mixing of two deposits of different ages. Station 3804, where the mixing is

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most thorough, is on the shallowest part of Galicia Bank, and redeposition of eroded Cretaceous coccoliths is improbable in such an exposed situation. A more likely explanation is that the mixing was brought about by mud-feeding organisms burrowing beneath the sea-floor. The unlithified Cretaceous deposits of Galicia Bank are probably overlain directly by similar material of Eocene age, and disturbance during the deposition of the first few centimetres of this Tertiary cover would result in mixed assemblages such as those of Stations 3804 and 3808. Such mixing of sediments by burrowing animals is now known to be very widespread on the ocean floor; indeed Arrhenius (1952, p. 86) has remarked that the absence of its effects indicates abnormal conditions, such as a very high rate of deposition. The effects are most conspicuous when there is an abrupt change in the properties of the sediment: in its colour, its petrological composition, or its fossil-content. The first produces a distinctive colour-mottling (Ericson *et al.* 1961, pl. 2, fig. 2), and an example of the vertical redistribution of volcanic glass in deep-sea sediments has been described by Bramlette and Bradley (1940, p. 22). Ericson found that 'normal mud feeders rarely penetrate much more than 10 cm. below the sediment–water interface and that really significant mixing of sediment by burrowers is confined to the uppermost 5 cm.' It is not surprising therefore that only two of the samples examined have yielded this anomalous mixture of Cretaceous and Tertiary species.

All the samples examined from Station 3808 contained a remarkable assemblage of coccoliths dominated by *Coccolithus marismontium* and its associates, *C. lusitanicus*, *C. muiri*, and *Ericsonia alternans*, to be described on a later page. None of these has yet been found at any locality on shore, and the age of the assemblage must be determined by the other fossils associated with it. These include a few examples of *C. eopelagicus* Bramlette and Riedel, *Braarudosphaera discula* B. and R., and *Discoaster aster* B. and R. The presence of these three species together in the same rock suggests a Middle Eocene age. Dr. B. M. Funnell has examined the foraminifera, and finds that they also indicate a horizon within the Middle Eocene.

The same assemblage has been seen in core A150–1, from Muir Seamount. *C. marismontium* and its associates are abundant in a coccolith ooze 125–6 cm. below the top, at which level the core also contains Middle Eocene foraminifera. A form which appears to be identical with *C. marismontium* has recently turned up in a deep-sea core (DWBG 23B) from the Pacific Ocean, where it is again associated with Middle Eocene foraminifera.

On this evidence, there can be little doubt that the *C. marismontium* assemblage of Galicia Bank and Muir Seamount is of Middle Eocene age, and it is remarkable that these species have not yet been found in rocks exposed on land. It is just possible that these are strictly pelagic forms which avoided the shallow seas in which the Eocene rocks of western Europe were deposited, but this does not seem likely in view of the cosmopolitan distribution of other Tertiary assemblages. Since they are all rather small forms, difficult to identify under the light-microscope, an alternative explanation may be that they are short-ranged species, confined to a relatively thin stratigraphical unit that has not yet been examined under the electron microscope.

SYSTEMATIC DESCRIPTIONS

In the following descriptions, specimens of coccoliths are identified by their serial numbers in the reference collection of electron micrographs at the Sedgwick Museum,

Cambridge. Photographs by P. J. W. Hyde of chromium-shaded carbon replicas taken with an Associated Electrical Industries EM 6 electron microscope provided by a grant from the Department of Scientific and Industrial Research.

Coccolithus lusitanicus sp. nov.

Plate 50, figs. 1, 2

Diagnosis. Placoliths of approximately circular outline consisting of two shields surrounding a relatively flat central area 50 to 60 per cent. of the diameter of the complete coccolith; central area usually, but not always, with a circular central perforation.

Holotype. 11605, from Galicia Bank, Discovery 3809.1.

Dimensions of holotype. 7·3 × 7·0 μ; central area 4·3 × 3·8 μ. Thirty-nine rays.

Range of dimensions. Of the numerous specimens examined, twenty-one were measured in detail, giving the following ranges: overall diameter 6·5–8·5 μ, exceptionally up to ten; central area 3·8–5·5 μ; perforation commonly 0·8–1·0 μ, exceptionally up to 1·5 and down to 0·1, or apparently absent. Rays 39 to 51.

Distribution. Abundant in soft chalky limestone dredged at Discovery Stations 3804, 3808, and 3809 on Galicia Bank; less abundant, but not rare, in coccolith ooze from core A150–1, Muir Seamount. At present unknown from any locality on land.

Horizon. Middle Eocene.

Description. The rays are straight with gently rounded ends, overlapping, and flat-surfaced. The central area is approximately circular, and has a saw-toothed margin at the circumference. Its structure is not always easy to make out; in clean, well-preserved specimens it is seen to consist of closely fitted radial elements, about twenty in number near the centre, but increasing by insertion until near the circumference they are approximately equal in number to the rays in the distal part of the shield. In most specimens, the radial elements of the central area are smooth-sided, but in a few they are finely crenulate (Pl. 50, fig. 2). More than half the specimens examined have a clearly defined central perforation, usually slightly less than 1 μ in diameter, but there is considerable variation in size. In many of the others, the place where a perforation might be expected is obscured by fine debris, but there remains a small number of coccoliths in which the centre appears to be perfectly clean and shows no trace of a hole. In the main, it is the larger coccoliths that tend to be imperforate; they may have been borne on some special part of the living cell, in the same way that modified coccoliths are localised by some modern species in the apical or equatorial regions.

In its general appearance, *C. lusitanicus* resembles the form figured by Hay and Towe

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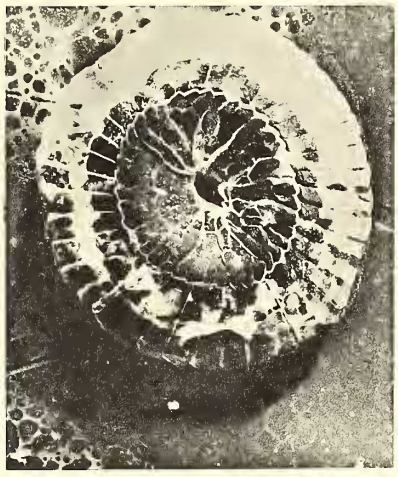
EXPLANATION OF PLATE 50

All figures × 6,000.

Figs. 1–2. *Coccolithus lusitanicus* sp. nov. 1, External view of holotype, No. 11605 from Galicia Bank, Discovery Station 3809, Sample 1. 2, External view of No. 11066 from Muir Seamount.

Figs. 3–4. *Coccolithus muiri* sp. nov. 3, External view of unusually broad specimen; No. 11656 from Muir Seamount. 4, External view of holotype No. 11666 from Muir Seamount.

Figs. 5–6. *Coccolithites turbatus* sp. nov. 5, No. 13677 from the Lower Maestrichtian Chalk of Sidestrand, Norfolk. 6, Holotype, No. 10957 from Galicia Bank, Discovery Station 3804, Sample 1.



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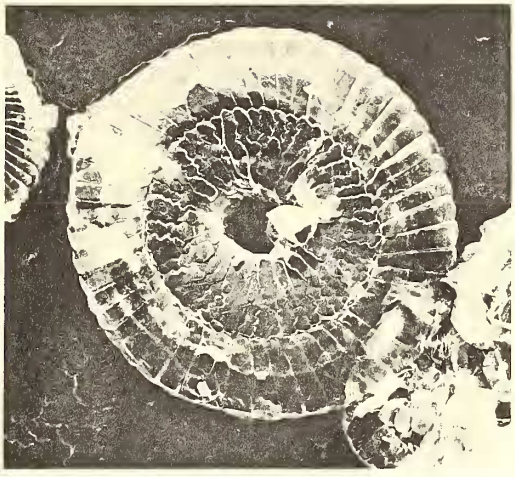

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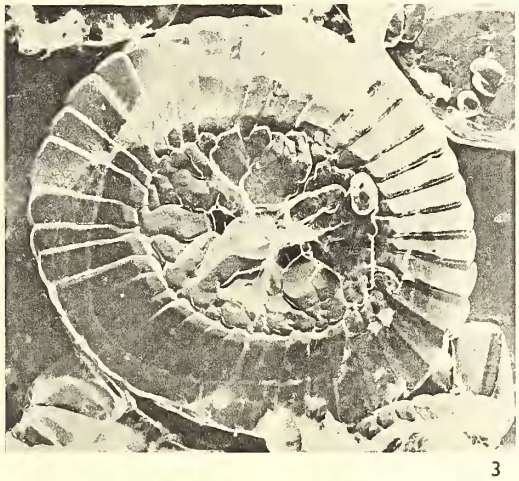

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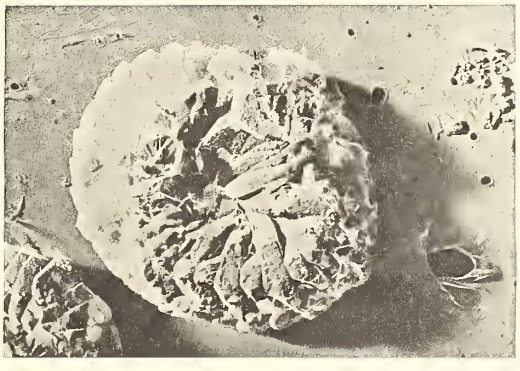

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BLACK, Cretaceous and Tertiary coccoliths

(1962, p. 500 and pl. vi, fig. 5) as the basal shield of *Cyathosphaera diaphragma* Hay and Towe, but the dimensions given by Hay are smaller (2·7–4·5 μ) and entirely outside the range for *Coccolithus lusitanicus* (6·5–8·5 μ). Furthermore, in the best preserved specimens of our species the central area is smooth and shows no sign of having lost an additional disc by fracture.

Coccolithus marismontium sp. nov.

Plate 51, figs 1–4; Plate 52, fig. 3

Diagnosis. Elliptical to nearly circular placoliths with the smaller shield about three-quarters the diameter of the larger, each consisting of narrow slightly flexuous rays, between 38 and 65 in number, not appreciably overlapping.

Holotype. 11048, from the Muir Seamount.

Dimensions of holotype. Larger shield 6·9 × 6·0 μ; smaller shield 5·2 × 5·1 μ; pore 2·0 × 1·5 μ. Fifty rays in each shield.

Range of dimensions. Larger shield 5·0–8·0 μ; smaller shield 4·0–6·0 μ; pore 1·2–2·5 μ. Rays 38–65, approximately equal numbers in the two shields.

Distribution. Abundant in soft chalky limestone dredged at Discovery Stations 3804, 3808, and 3809 on Galicia Bank; abundant in core A150–1, Muir Seamount; common in core DWBG 23B, Pacific Ocean. At present unknown from any locality on land.

Horizon. Middle Eocene.

Description. This is a variable but easily recognized species. The rays lie side by side without appreciable overlap, and their exposed surfaces tend to be slightly swollen; each ray terminates in a blunt point. On the internal surface, the rays are sharply bent towards the pore, forming a central depression whose diameter is equal to about two-sevenths of the width of the coccolith. There is a similar but wider depression in the larger shield, within which lies a ring of broad, polygonal plates surrounding the central pore; these plates are loosely attached, and in many specimens the ring is incompletely preserved or entirely missing. The pore is usually about 2·0 μ in greater diameter and broadly elliptical in shape.

Coccolithus muiri sp. nov.

Plate 50, figs. 3, 4

Diagnosis. Placoliths of elliptical shape and somewhat irregular outline, with thirty to forty rays in each shield, and with a more or less depressed central area of variously shaped granules, with or without a slot-shaped pore along the major diameter.

Holotype. 11666, from Muir Seamount.

Dimensions of holotype. 8·5 × 7·1 μ; central area 5·0 × 3·4 μ. Thirty-five rays.

Range of dimensions. Overall length 6·5–10·5 μ; central area 4·0–6·0 μ. Rays 30–40.

Distribution. Abundant in core A150–1 from Muir Seamount; frequent in soft chalky limestones dredged at Discovery Stations 3804, 3808, and 3809 on Galicia Bank (Black, Hill, Laughton, and Matthews 1964, pl. 44*c*). At present unknown elsewhere.

Horizon. Middle Eocene.

Description. The rays are straight-sided and flat, overlap each other, and have gently rounded terminations, which are sometimes slightly oblique. In these respects they are much like the rays of certain other species of *Coccolithus*, such as *C. pelagicus* (Wallich) and *C. sarsiae* Black (1962, pl. ix, figs. 2–6). *C. pelagicus*, however, has much larger coccoliths with more numerous rays (Black 1963, pl. 1, fig. 7), whilst *C. sarsiae* is a smaller form with more crowded rays than *C. muiri*. In *C. lusitanicus*, which also has rays of this type, they are more numerous, the central area is differently constructed, and the pore when visible is nearly circular.

Coccolithites turbatus sp. nov.

Plate 50, figs. 5, 6

Diagnosis. Broadly elliptical to nearly circular coccoliths consisting of two layers of roughly radiating elements, closely packed together, but not forming distinct shields.

Holotype. 10957 from Station 3804, Galicia Bank.

Dimensions of holotype. $7{\cdot}2 \times 5{\cdot}7\ \mu$, with about thirty-two rays at the periphery.

Range of dimensions. Major diameter 5·8–8·8 μ. Rays about thirty-two, difficult to count in most specimens.

Distribution. On Galicia Bank it is common in chalky limestones at Station 3804, where it is associated with various Upper Cretaceous and Lower Tertiary species, and at Station 4272, where it is the only species that can be identified. Rare in the chalk of Sidestrand, Norfolk (Lower Maestrichtian).

Horizon. Upper Cretaceous, at present only known in the Maestrichtian.

Description. Eight or more radial elements arise from the centre, and by insertion of additional rays increase to about thirty-two at the periphery.

Kamptner's name *Coccolithites* is used for this species since it cannot be assigned to any known genus, and its structure is too obscure to justify the creation of a new generic name.

Genus COLVILLEA gen. nov.

Diagnosis. Coccoliths consisting of two elliptical shields in contact with each other; external shield larger than the internal, both curved, with the concave surface on the internal side.

Type species. Tremalithus barnesae Black.

Discussion. As Bramlette and Sullivan (1961, p. 138) have pointed out, the use of Kamptner's paragenus *Tremalithus* for species founded upon isolated placoliths like those of *Coccolithus* is unnecessary, and such species are now usually included in *Coccolithus*. *T. barnesae*, in which the two shields are in contact and are not pierced by

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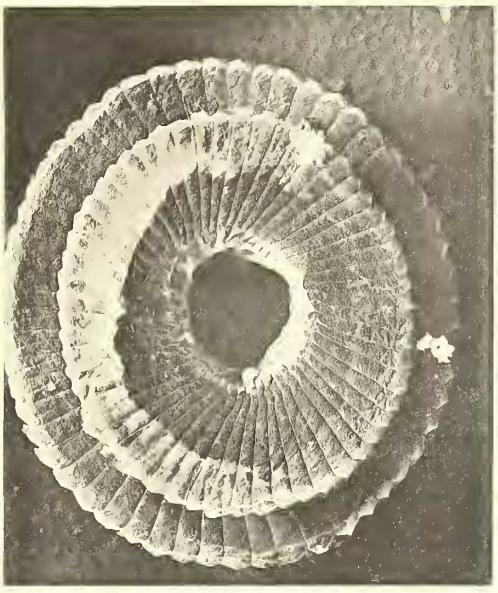
EXPLANATION OF PLATE 51

All figures ×8,000.

Figs. 1–4. *Coccolithus marismontium* sp. nov. 1, Internal view of exceptionally clean specimen No. 14278 from the central Pacific. 2, External view, showing a common state of preservation; No. 11058 from Muir Seamount. 3, Internal view of holotype No. 11048 from Muir Seamount. 4, External view of specimen with the central ring preserved; No. 10925 from Galicia Bank, Discovery Station 3808, Sample 5.



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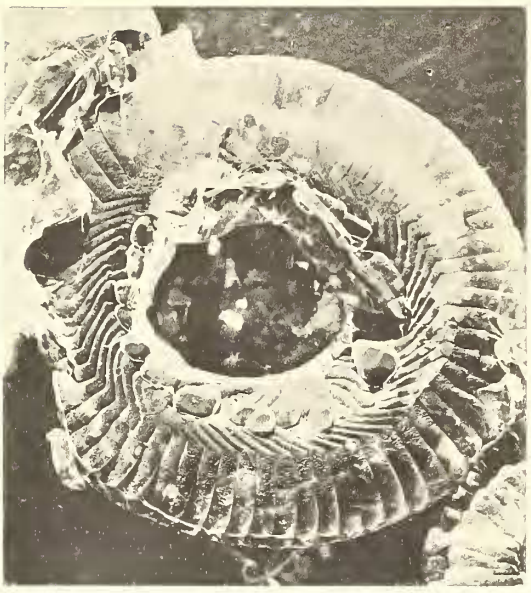

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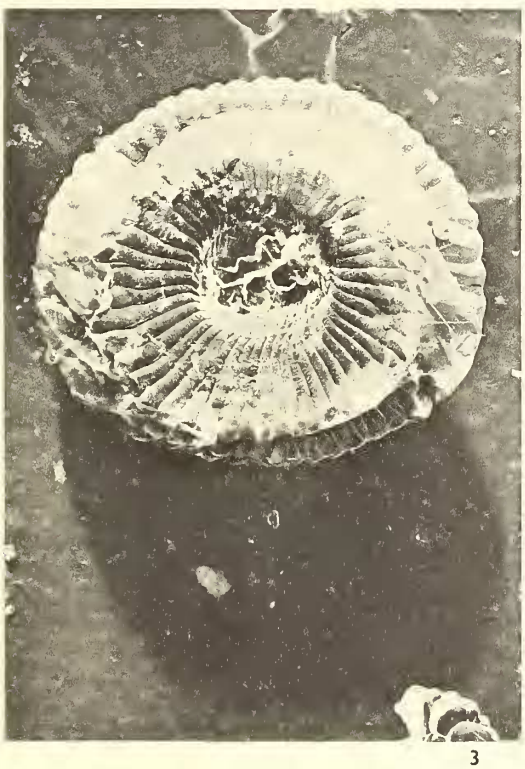

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BLACK, Tertiary coccoliths

a pore, cannot be transferred to *Coccolithus*, nor can it remain in *Tremalithus* as thus interpreted, since complete spheres are now known. It would also be excluded by Kamptner's redefinition of *Tremalithus* as a genus to include species bearing placoliths modified by suppression of the inner shield (Kamptner 1958, p. 82). A new generic name is therefore required to accommodate this and several related species which are abundant in the Cretaceous.

Colvillea barnesae (Black) comb. nov.

1959 *Tremalithus barnesae* Black, in Black and Barnes 1959, p. 325; pl. ix, figs. 1, 2.

Revised description. Coccoliths imperforate with two broadly elliptical or nearly circular shields, one slightly smaller than the other, and each consisting of 28 rays (exceptionally 27 or 29). Rays of the smaller shield gently curved, filling the centre, in contact for their whole length but not overlapping, slightly swollen and bluntly pointed at their distal ends. Rays of the larger shield not reaching the centre, but radiating obliquely from an oval ring of quadrate granules, smooth at the external surface, and obliquely truncated at their distal ends.

Distribution and horizon. C. barnesae is common in the chalks of Europe, Australia, and North America. It ranges from the Cenomanian to the Maestrichtian, but is not known outside these limits. In the Iberian Seamounts, this species was recorded in the soft chalky limestones dredged at Discovery Stations 3804 and 3809 on Galicia Bank.

Genus ERICSONIA gen. nov.

Diagnosis. Circular or elliptical coccoliths with a well-defined central opening surrounded by three or more apparently concentric rings of granules which are differently orientated in adjacent rings.

Type species. Ericsonia occidentalis sp. nov.

Discussion. The interior structure of these coccoliths is at present imperfectly known. They give the impression of having a wide, perforated disc made of rays extending from the central opening to the periphery. The other rings are narrower; they surround the central opening and appear to overlie the principal disc. They consist of vertical or inclined granules which in some species give a herring-bone pattern due to the opposite inclination of the granules in two adjacent rings.

Three species are known in sediments of Lower Tertiary age from seamounts in the Atlantic Ocean. The genus also appears to be represented in the Danian by one or two undescribed species.

Ericsonia occidentalis sp. nov.

Plate 52, figs. 1, 2

Diagnosis. Nearly circular *Ericsonia* with three concentric rings, the second and third rings from the outside consisting of narrow crystals inclined in opposite directions, producing a chevron pattern.

Holotype. 11667, from Muir Seamount.

Dimensions of holotype. $8{\cdot}4 \times 7{\cdot}8\,\mu$; second ring $6{\cdot}0 \times 5{\cdot}9\,\mu$; third ring $4{\cdot}3 \times 3{\cdot}9\,\mu$; pore $2{\cdot}5 \times 2{\cdot}0\,\mu$. Forty rays in the outer ring.

Range of dimensions. In the few specimens available, the major diameter ranges from 6·7 to 8·4 μ, and the number of rays at the outer margin from twenty-eight to forty. Departures from a circular shape are slight, and the minor diameter is always more than nine tenths of the major.

Distribution. Known only from Muir Seamount.

Horizon. Middle Eocene.

Comparison. E. occidentalis is easily distinguished from the other species described below by having three rings instead of four, and by the striking herring-bone pattern of the second and third rings.

Ericsonia alternans sp. nov.

Plate 52, fig. 4

Diagnosis. Nearly circular *Ericsonia* with four concentric rings and a nearly circular central opening.

Holotype. 10954, from Galicia Bank (Discovery 3804.1).

Dimensions of holotype. 7·0 × 7·0 μ; second ring 6·3 × 6·0 μ; third ring 5·2 × 4·8 μ; inner ring 3·1 × 2·7 μ; pore 1·1 × 1·0 μ. About forty-five rays.

Range of dimensions. Diameter 6·0 to 8·8 μ. Rays in the outermost ring thirty-two to forty-five. All the specimens examined appeared circular to the eye, but measurements usually show a slight departure from the strictly equidimensional form; in extreme examples the minor diameter is only nine-tenths of the major.

Distribution. Muir Seamount and Galicia Bank (Discovery Stations 3804, 3808, and 3809).

Horizon. Middle Eocene.

Description. There is some variation in the appearance of the component rings, which in part at least seems to depend upon the state of preservation of individual specimens. The granules in the second ring from the outside tend to be narrow and are inclined at an angle which may be as much as 45° to the radial direction. The granules of the third and fourth rings are for the most part keystone-shaped or quadrate, and the sutures separating them are directed radially.

Ericsonia ovalis sp. nov.

Plate 52, figs. 5, 6

Diagnosis. Elliptical *Ericsonia* with four concentric rings, and an elongate central opening.

EXPLANATION OF PLATE 52

Figs. 1–2. *Ericsonia occidentalis* sp. nov. 1, Holotype No. 11667 from Muir Seamount, × 6,000. 2, Details of second and third rings; No. 10005 from Muir Seamount, × 10,000.

Fig. 3. *Coccolithus marismontium* sp. nov., internal view showing a common state of preservation on the Iberian Seamounts, with slightly damaged internal disc; No. 10966 from Galicia Bank, Discovery Station 3804, Sample 1, × 6,000.

Fig. 4. *Ericsonia alternans* sp. nov., holotype; No. 10954 from Galicia Bank, Discovery Station 3804, Sample 1, × 6,000.

Figs. 5–6. *Ericsonia ovalis* sp. nov., × 6,000. 5, No. 11650 from Muir Seamount. 6, Holotype No. 11659 from Muir Seamount.